Ecological-edaphic and Socio-economic drivers of on-farm tree farming enterprises in Wakiso District, Central Uganda

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Abstract**—** *The biophysical-edaphic and socio-economic factors do equally influence the on-farm tree farming in the smallholder farming systems. Naturally, neither of the factors do act in isolation, but they are interrelated. The study was carried out in Nsangi sub-county, Wakiso District, 2018. Using the stratified random sampling method based on landholding sizes, a sample of size of sixty households were selected and interviewed. The objectives of the study were to examine the influence of the bio-physical, edaphic and socio-cultural-economic factors onto the performance of the on-farm tree farming enterprise, and to evaluate the farmer's participation in on-farm tree farming activities. The results showed that both ecological-edaphic and socio-cultural-economic factors influence the performance of the tree volume, tree species diversity and tree stand density/ha. There is a negative correlation between size of landholding and farmer's interaction with the on-farm tree farming enterprises. Judging from the results of this study, there is a need for a policy review aimed at devising appropriate socio-cultural-economic and ecological-edaphic practices that promote on-farm tree farming programmes.*

Keywords**— *On-farm tree farming enterprise, ecological-edaphic, socio-cultural-economic factors.***

I. INTRODUCTION

Uganda has got approximately 14,900 km^2 of gazetted forest reserves of which some 7,500 km^2 (4%) is savannah woodland and forest plantation, 5,900 km^2 (3%) is tropical high forest and 1,500 k^2 (1%) montane catchment forest (Uganda Forest Department, 1951; Banana and Gombya-Ssembajjwe, 2000). Conversion of natural forests into agricultural land became a serious problem in Uganda in 1970's of which 12% of forested land had been affected by this agricultural encroachment (Banana and Gombya-Ssembajjwe, 2000).

About 53% of forestland within Uganda's forest reserves remains essentially undisturbed (MWLE, 2001a). Deforestation was particularly severe between 1970 and 1985 when government control over forests deteriorated. A high population growth rate, conversion of forest land to agricultural uses as well as break down in law and order have been the major causes for deforestation in Uganda (MWLE, 2002b).

These forests are an essential foundation for the country’s current and future livelihood and growth. Sustainable management of these forests, however, poses great challenges given that the population is heavily dependent on them for timber, agriculture, and energy production (Buyinza and Nabalegwa, 2007). Forests and woodlands covered approximately 45% of the total land area of Uganda in 1898. At present, forest cover has been reduced to approximately 4.9 million hectares or about 20% of the total land area (MWLE, 2002b). About 30% of the tropical high forests are degraded and the degradation trend continues. Without effective institutions to limit and regulate harvesting levels and management practices, forest resources can be over-harvested and even irreversibly destroyed, as is the case in “open access” forests (Galabuzi et. al., 2014).

Many contemporary on-farm tree management policies in both developed and developing countries are therefore seeking to shift control of tree resources to the community level in an attempt to improve management of local tree resources. Empowering local communities to monitor and enforce tree management rules significantly lowers monitoring costs and improves effectiveness because, according to Galabuzi et. al., 2014, when compared to central government institutions, local institutional arrangements are considered better at providing, *inter alia*, rules related to access, harvesting, and management; a forum that can respond to conflict quickly and cheaply; and monitoring and sanctioning methods that are efficient.

The goal of this study was to examine the biophysical-edaphic and socio-cultural-economic factors that influence the potential of the on-farm tree farming practices.

The specific objectives were to (a) identify the relationship that exists between the socio-cultural-economic condition of the farmer with the potential of the on-farm tree farming enterprises, (b) to discover the relationship between the size of landholding and farmer's interaction (work-time) with the on-farm tree enterprises.

The research hypothesis were (1) the biophysical-edaphic and socio-cultural-economic factors influence the performance of the on-farm tree enterprises as indicated by tree volume (m^3), tree species diversity index and tree stand density / ha; (2). The farmer's interaction (work-time) with the on-farm tree enterprises depends on the size of landholding and total number of livestock held.

1.1 Description of the study area

Nsangi Sub-county is located in Wakiso District, South West Uganda. It lies between latitude 0^o13^oN and 0^o20^o N and longitude 32^o24^oE and 32^o33^oE. It covers a surface area of 107 km^2, supports a population of 44,117 people with an average population density of 412 inhabitants per km^2. The area is found within the Lake Victoria basin characterized by a relatively favorable climate i.e reliable rainfall amounting to 1000 mm annually, bi-modal type of rainfall with peak falls in March to May and October to November, has a mean annual maximum temperature of 26^0c and annual minimum temperature of 17^0c.

The area has under undifferentiated gneiss including elements of Pre-cambrian partly granitized and metamorphosed formations. Geologically, the area follows under the Buganda-Toro systems comprised of agilities, phyillites and schist with basal quartzite and amphibolites. It is characterized by flat-topped mesa like hills, which show considerable uniformity of elevation. Like other areas in southwestern Uganda, Nsangi sub-county has got dissected slopes of 1260 meters and at a much higher altitude of 1290 meters associated with many ridges.

The dominant soil type is sandy loams (ferrallitic soils) which represent almost the final stage in tropical weathering. From field observations, the soils of most ridges are ferrallitic, shallow soils ranging from course to stony and bare rock (skeletal soils) or rock out-crops on hill slopes with lateritic soils at the top of hills. The valleys are filled with deeply leached and weathered lateritic soils. The rest of the low land is covered by clay loams, which support agriculture in the area.

The dominant vegetation is savannah mosaic, which covers elephant grass (*pennisetum perpurem*) with isolated forest and savannah trees, which are remnants of a previous forest cover and cultivation demonstrating its intermediate and mixed character. However, today with the increasing population, the vegetation has been cleared for other intensive land use practices such as grazing, brick making, and excavation of stones and extension of land for cultivation and settlement.

II. MATERIALS AND METHODS

The data was obtained from a household survey conducted in July 2018. The primary data was collected using direct measurements, observations, conducting interviews and group discussions with the local people. Secondary data was got from District Forest Support Services and National Forestry Authority. The 60 sample respondents were chosen using the stratified random sampling technique based on the size of land (ha) owned. There strata were formed, namely, Strata I: (< 0.5 ha), Strata II (0.6 - 1 ha), and Strata III (> 1.0 ha). The dependent variables included tree volume (Y_1), tree species - diversity index (Y_2), total time spent working in on-farm tree enterprise (Y_3), and tree stand - density / ha (Y_4) whereas the independent variables were: slope length (X_I), soil erodibility (X_2), slope steepness (X_3), total size of landholding (X_4), age of head of family (X_5), education level of head of family (X_6), social - economic status of head of family (X_7), total family size (X_8), farming experience of head of family (X_9), intensity of extension services (X_{10}), livestock owned (X_{11}), fuel wood consumption / day (X_{12}), and dummy variable (V_I).

2.1 Data analysis

The multiple linear regression and correlation model was used in data analysis. The model involved computation of correlation coefficient (r); multiple regression analysis (T-test); analysis of variance (F-test); coefficient determinant (R^2); and regression coefficient (SE-B)

This model was chosen basing on the fact that the on-farm tree management enterprise potential is influenced by many interacting but different physical, edaphic and socio-economic environmental factors. Using the technique of "dummy variables", several qualitative factors such as intensity of extension services were included in the regression.

The multiple linear regression model was used to assess the collective or individual contribution of two or more independent variables towards the dependent variable:

$$Y_1 = B_0 + B_1X_1 + B_2X_2 \ldots .. + B_nX_n + e.$$

Where: Y_1 = predicted value; B_0 = Y – intercept (constant), B_1 = partial regression coefficient of X1, X_1 = independent (explanatory or predictor) variable, E = error (external factor).

The analysis of multiple correction coefficients was intended to identify the strength of the relationship between the dependent and independent variables. The hypothesis were tested and decisions taken basing on the 95% ($\alpha = 0.05$) degree of confidence. According to Sutrisno (1989), hypothesis can be analysed through a series of statistical stages, in order to identify relationship between dependent and independent variables, multiple correlation coefficient (r) is necessary in predicting the effect of the independent onto the dependent variable. The standards to consider in decision-making were: $0.500 < r > 0.700$ proper for prediction, $0.250 < r > 0.500$ doubtable for prediction and $0.000 < r > 0.250$ practically not good for prediction

III. RESULTS AND DISCUSSION

Basing on the tree volume, tree species diversity index, and tree stand density, the potential of the on-farm tree management enterprise is greatly determined by the physical, edaphic and socio-cultural-economic characteristics of the farmer. The purpose of this study was to examine the physical and edaphic factors that affect the performance of the on-farm tree farming. The physical factors studied included slope length, slope steepness and soil erodibility.

Many socio-economic and cultural factors do influence the adaptation and management of trees in the farming systems of the local farmers. Naturally, these factors do not act in isolation but they are interelated with other institutional factors.

The varied topography of Nsangi sub-county results in wide variations in the soil types and fertility, microclimate and vegetation over short distances. These diversified agro-ecological-edaphic, landscape, morphology, lithology, and topographical conditions have given rise to a diversity of tree species. The tree species diversity index (Y_2) is strongly influenced by local physical and edaphic factors such as slope length, slope steepness and soil erodibility as shown by the coefficient determination ($r^2 = 0.41466$) 41% of the variations in the tree diversity index. There is a strong positive relationship between slope length ($rX_1Y_2 = 0.508$), soil erodibility ($rX_2Y_2 = 0.487$) with the tree species diversity index (Y_1) as illustrated in the mathematical regression model:

$$Y_2 = 2.569016 + 416744X_1 + 410436X_2$$

Of the three physical factors, the slope length (X_1) shows the greatest influence over tree species index whereas slope steepness (X_3) has the least influence. Therefore, using the backward regression method, only slope length and soil erodibility are important towards tree species index. The slope length shows the biggest relationship ($r = 0.5077$), hence can reliably be used for the prediction of the future condition of tree species index. The soil erodibility gives doubtable results with very small relationship ($r = 0.0520$) which practically should not be used for predictions of the potential of the on-farm tree enterprise.

There is a strong positive relationship between tree species diversity index (Y_1) and slope length ($rX_1Y_2 = 0.5077$**), soil erodibility ($rX_2Y_2 = 0.4865$**) at confidence interval $\alpha = 0.001$, this implies that highly eroded soils are planted with different tree species and long slopes have got more diversity of tree species. The successful establishment and growth on-farm tree enterprise depend largely on correct choice of species, soil working methods, silvi-cultural practices and management techniques suited to the different species and site conditions.

There was a weak relationship between slope steepness and tree species diversity index ($rX_3Y_2 = 0.052$), this was because the area is generally of uniform steepness with minor differences which did not significantly affect the species diversity. However, under normal conditions the steeper the slope the more the diversity of tree species planted.

Direct observation revealed that diversity of tree species largely depended on the size of the landholding. Households owning large pieces of land had a big tree species diversity index compared to those with smaller plots of land. It was deduced that owing to marked differences in rooting habits, physiological requirements, growth pattern and life cycle, the physical (slope length and steepness) and edaphic (soil erodibility) factors do influence the performance of the on-farm tree enterprise.

The hypothesis which states that the local physical and edaphic factors influence tree species diversity index is therefore accepted.

The socio-economic condition of the household determines the tree species diversity index in the on-farm tree enterprise. The household demand for fuelwood poses the greatest influence on tree species diversity index. There is a positive relationship between tree species diversity and fuelwood consumption ($rX_{12}y_2 = 0.535$). The big families that require large quantities of fuelwood planted a variety of tree species to meet their needs and objectives. Some trees species are planted for economic motives whereas others for soil conservation purposes and also for cultural advantages.

The size of landholding affects the tree species diversity index ($rX_4Y_2 = 0.0504$), whereby households with big plots of land plant a variety of tree species to serve their ecological-edaphic, economic and social requirements. There is a negative relationship between the level of formal education and intensity of extension services with tree species diversity ($rV_1Y_2 = -0.2287$), this means that the farmers have not responded positively to advise given by extension field workers, this is true because the farmers are poor and fear to undertake risks of investing in expensive, exotic tree species instead continue with the traditional farming methods long used by their grandparents.

The physical and edaphic factors do not have significant influence towards the tree volume (m^3) or actual standing stock. This is because the area is generally homogeneous with a standard deviation of only 2.6%, slope steepness ranges from 15 - 24% hence slope steepness does not have an significant influence towards tree volume. The three factors explain only 0.6% of the total variation in tree volume (m^3). The remaining 99.4% is because of factors other than those examined in this study. The sizes of the household and total landholdings are the two socio-economic factors that affect the tree volume (m^3) as illustrated by the linear model: $Y_1 = 5.384 + 0.841X_8$

The positive relationship between total number of household members and tree volume ($rX_8Y_1 = 0.362$) suggests that big families have got big labour force to plant and manage big tree volumes. The tree volume also depends on the size of the total land owned whereby farmers who own bigger plots of land tend to plant extensive area with trees. However, it was observed that tree volume also depend on edaphic and biological factors such as soil fertility. Tree density per hectare is greatly influenced by physical factors (slope length and soil erodibility) as shown by the mathematical model: $Y_4 = -363.1432 + 0.3986X_2 + 0.4235X_1$

There is strong positive correlation relationship between slope length and tree stand density / ha ($rX_IY_4 = 0.506^{**}$), this implies that that the longer the slope length, the more close (densely populated) are the tree stands planted with the aim of protecting the soil against erosional agents that cause surface run-off. The positive relationship between soil erodibility and tree stand density ($rX_2y_I = 0.484^{**}$) means that the soils that are highly susceptible to erosion are planted with very close tree stands to add on the resistance capacity of the soil against erosion. It was observed that the demand for fuelwood by a given family shows the greatest influence towards the tree stand density / ha as given in the mathematical model:

$$Y_4 = 545.42 + 0.549X_{I2}$$

There is a positive relationship between tree stand density and fuelwood consumption ($rX_{I2}y_4 = 0.5397$). Households with high fuelwood try to satisfy their needs by making optimal utilization of the land resource by planting trees very close to each other. There is a negative relationship between total size of landholding owned and the total time of work in the on-farm tree enterprise, $rX_4Y_3 = -0.6207$. The mathematical model showing the relationship is expressed as follows: $Y_3 = 385.323 - 196.579X_4$

The linear model a result suggests that farmers with big agricultural landholding interact less frequently with the on-farm tree enterprise; this is because their requirements such as fodder for livestock and fuelwood are fulfilled from their private landholdings. For purposes of comparison, farmers with less agricultural land spend more time searching for their tree products in the neighboring on-farm tree enterprise which forms a big proportion of total work-time. Households categorized under Stratum 1 (0.0 - 0.5 ha) is 32%, Strata II (0.5 - 1.0 ha) 25%, and strata III (> 1.0 ha) 22% of their total work time in on-farm tree enterprise looking for the tree requirements such as fodder, fuelwood and several other non-timber tree products. The farmer's interaction with the on-farm tree enterprise can be identified basing on the time allocation (work-time) in the on-farm tree enterprise. The activities carried out in the on-farm tree enterprises of Nsangi Sub-county are mainly informal activities such as collecting grass for livestock, gathering fuelwood for their subsistence. The two variables determine 38% ($R^2 = 0.382$) of the total work-time which implying that the two variables strongly influence the variations in the' total time of work in the on-farm tree enterprise for the 4 months of study. The estimated multiple regression equation: $Y_3 = 355.972 - 0.594843X_4 + 0.150083X_{1I}$

The estimating regression equation shows that total land owned determine the total time spent working in the on-farm tree enterprise.

Hypothesis 2 which states that farmer's interaction (work-time) with the on-farm tree farming activities depends on the size of landholding is accepted.

IV. CONCLUSION

The performance of the on-farm tree farming enterprise suggests that ecological-edaphic factors affect the survival and growth of plantation species while socio-economic factors affect the nature and extent of participation, however, ecological-edaphic factors have profound effects during the establishment stages, while community participation is significant on the protection level. Specifically, soil erodibility and slop length are some of the ecological-edaphic factors that significantly affect establishment of the plantations. Of the socio-cultural-economic factors, the major ones that significantly affect the success are demand for fuelwood, size and size of family landholding have the biggest influence on tree volume (m^3). Furthermore, knowledge and understanding about the program were crucial; however, community involvement in the project's identification, inception, planning, and organizational stages was achieved, bringing about favorable results during the implementation phase.

V. RECOMMENDATIONS

The on-farm tree farming practice should be encouraged through the provision of incentives and opportunities to the local people. Similarly, the District Local Forest Services and National Forestry Authority (NFA) should play an advisory role towards the development of no directive and participatory approaches in on-farm tree farming enterprise. The on-farm tree farming program should be revised to emphasis the contribution of the local people's participation in the design, the maintenance, and the utilization of the tree resource.

There is a need for a well-organized, consistent and continuous effort towards alleviating poverty through programs such Plan for Modernization of Agriculture (PMA), Universal Primary Education (UPE), Local Government Development Grant Programme (LGDGP), and National Agricultural Advisory Services (NAADS).

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